Multi-Mission Earth Entry Vehicle: Aerodynamic and Aerothermal Analysis of Trajectory Environments

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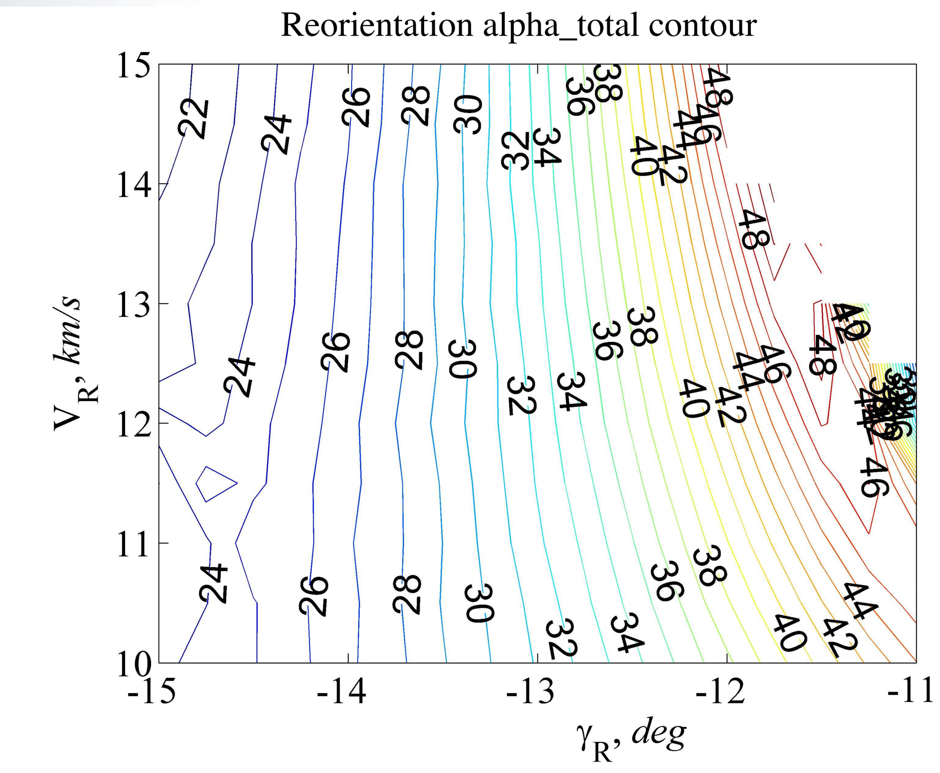
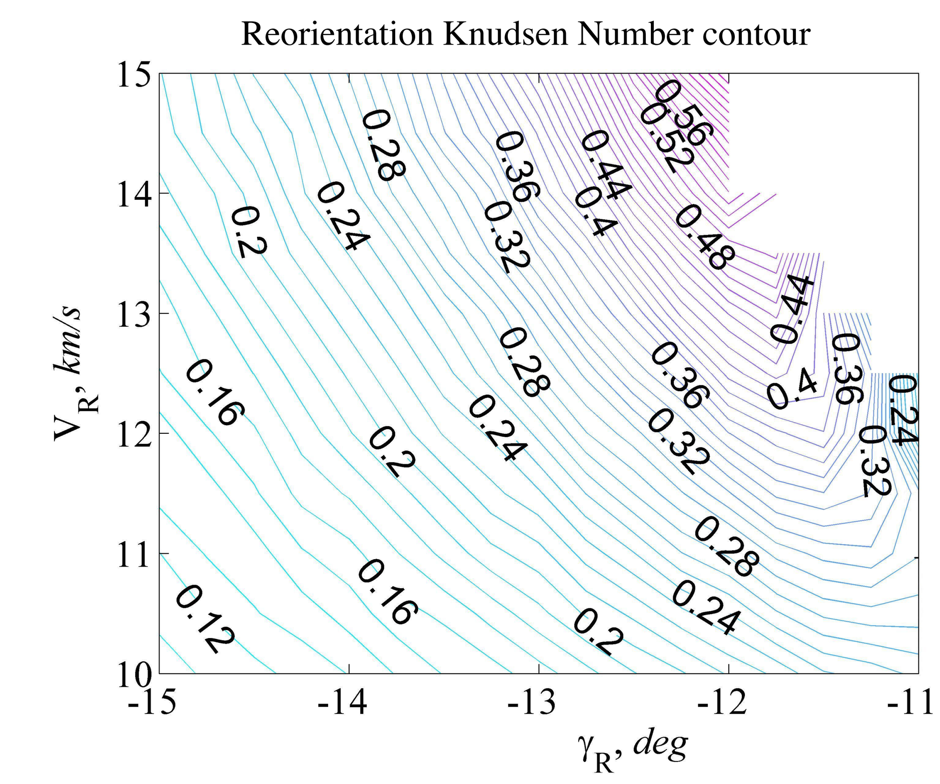
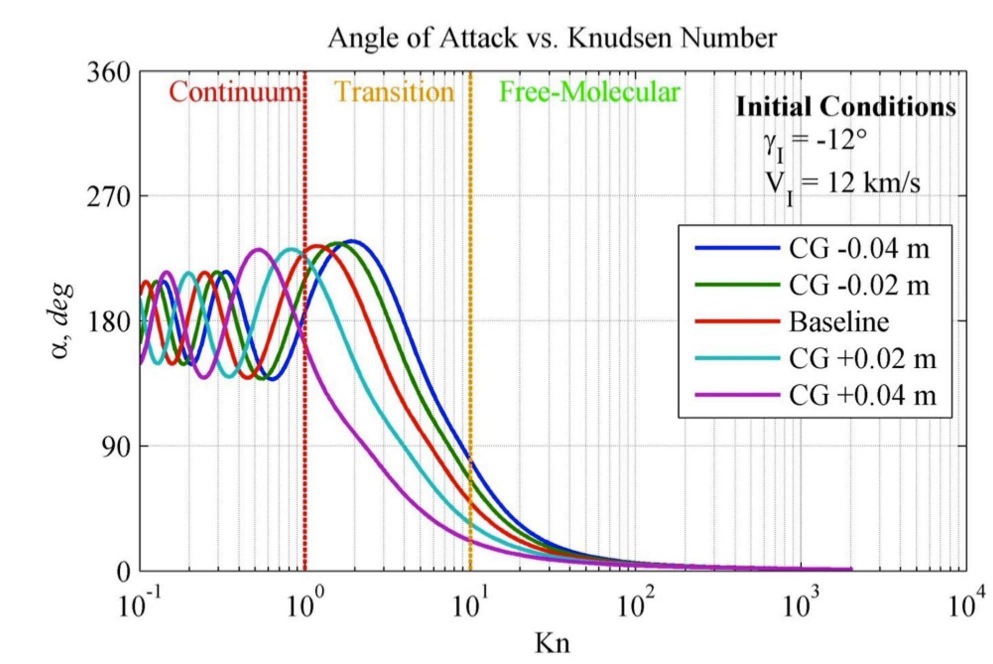
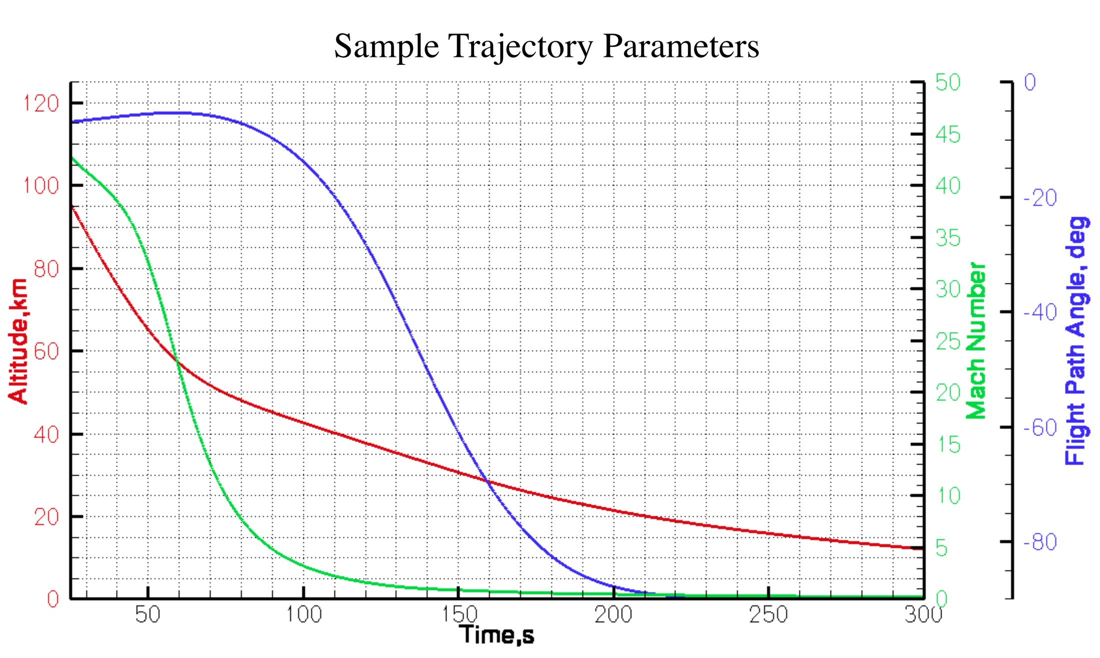
• Approach: Use CFD and existing tunnel data to assess stability and passive reorientation, and to characterize heating for thermal protection system sizing for multi mission Earth entry capsule.

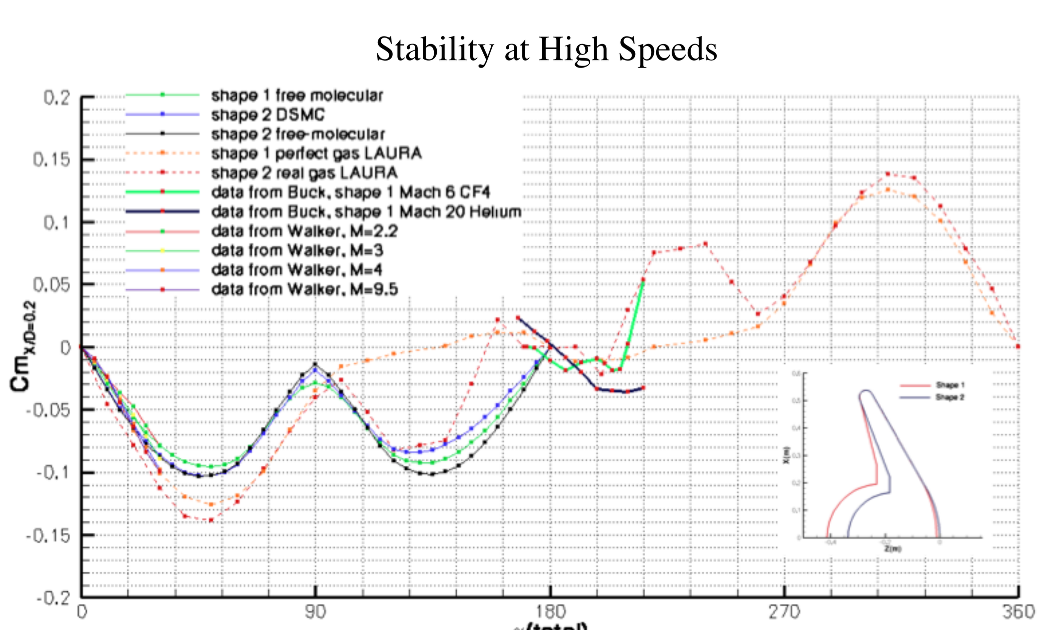
• Conclusions: Present approach leads to a good conservative approximation of performance over a broad range of trajectory parameters.

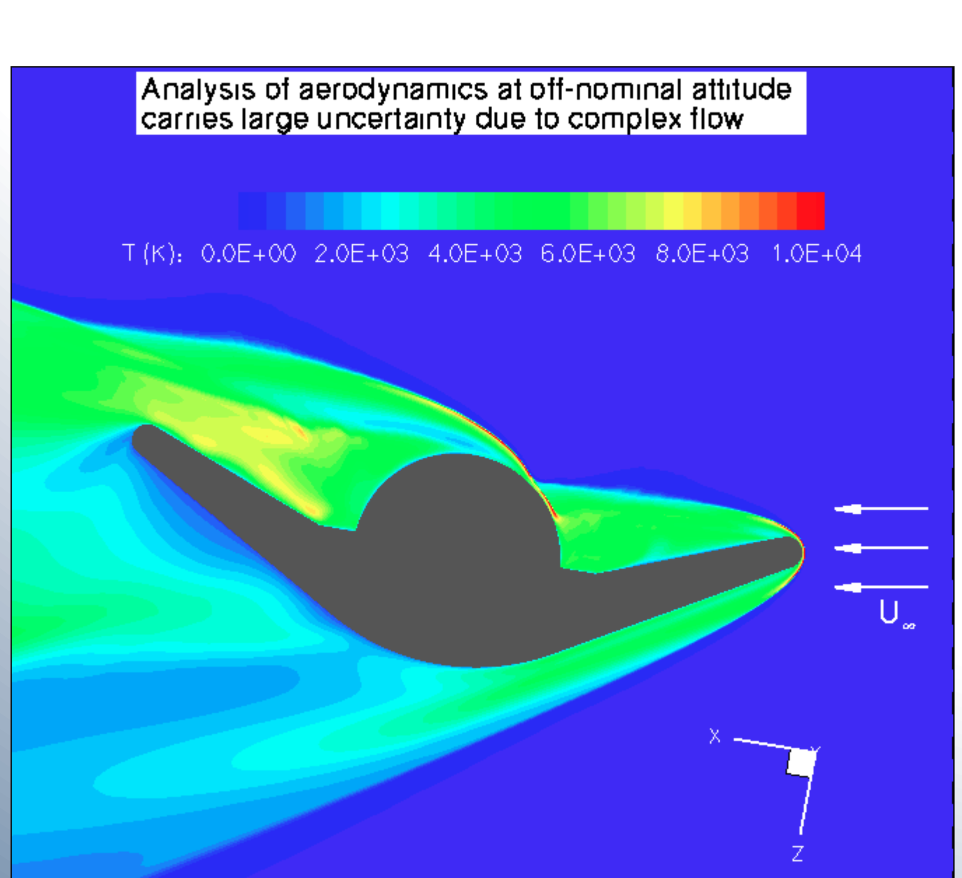












The Multi-mission Earth Entry Vehicle (MMEEV) project is developing a rapid analysis tool to scope the design of vehicles that can safely deliver small payloads from space to Earth's surface by flying an uncontrolled ballistic entry. The mission profile includes hypersonic, supersonic and subsonic environments and termination with ground impact. The included range of entry velocities is from 10 to 16 km/s. The range of ballistic coefficients is from 42 to 129 kg/m^2, which insures a low subsonic terminal velocity on the order of 50 m/sec. The range of entry flight path angles, considered in this analysis is from -5 to -25 degrees. The assessment and parametric characterization of aeroheating and aerodynamic performance of the capsule during entry is the subject of this work.

In order to accommodate requirements of various missions, the ballistic coefficient, the vehicle's diameter, and the entry states are varied within specified ranges. The vehicle will perform atmospheric entry and deceleration through hypersonic and supersonic regimes, and will reach subsonic velocity at high altitude. Much of the descent will be subsonic, terminating with low velocity impact at the Earth's surface. High confidence in aerodynamic characteristics is required to ensure reliability of an uncontrolled entry. An aerodynamics database of the MMEEV uses diverse sources, including DSMC, CFD, wind tunnel tests and ballistic range data. Performance in the rarefied atmosphere is described by rarefied calculations with DSMC Analysis Code (DAC) for angles of attack from zero to 180 degrees. Hypersonic aerodynamics are described by the non-equilibrium calculation of Langley Aeroheating Upwind Relaxation Algorithm (LAURA) for high flight enthalpy, and perfect gas air wind tunnel data at low enthalpy. Rarefied and hypersonic continuum data are blended through the transitional region, and the validity of this approach is confirmed by a full DSMC calculation. Wind tunnel data and ballistics range data is used for low velocity static aerodynamics and dynamic derivatives.

The aft-entry stability characteristics of the MMEEV concept vehicle are studied. A vehicle which achieves a monostable state within the free-molecular regime is required if passive entry is desired. Reorientation capability from aft-facing entry is studied and measured against initial conditions that define various trajectory scenarios. The analysis uses a high fidelity, six degree-of-freedom trajectory tool used with aerodynamic data from both heritage testing and computational data sources. Varied inputs include vehicle flight path angle, velocity, diameter, and payload mass.

The concept vehicle's thermal protection system (TPS) must be designed for a large matrix of entry velocities, ballistic coefficients and flight path angles. An aerothermal database is necessary to understand the environments the vehicle could experience. This parametric space is made up of 840 trajectories, too many for a high fidelity CFD code to perform affordable characterization of the heating. An engineering approach which is CFD-anchored with the Data Parallel Line Relaxation code (DPLR) was established to quickly characterize quantities pertinent to TPS design such as heat flux, heat load, and surface pressure. These quantities are inputs for material response modeling to size the TPS described in a companion study by Sepka, et. al.